



3rd International Workshop on a Far Detector in Korea for the J-PARC Neutrino Beam
Sep. 30 – Oct. 01 2007, Univ. of Tokyo, Hongo

Search for possible sites in Korea

2007. 10. 1

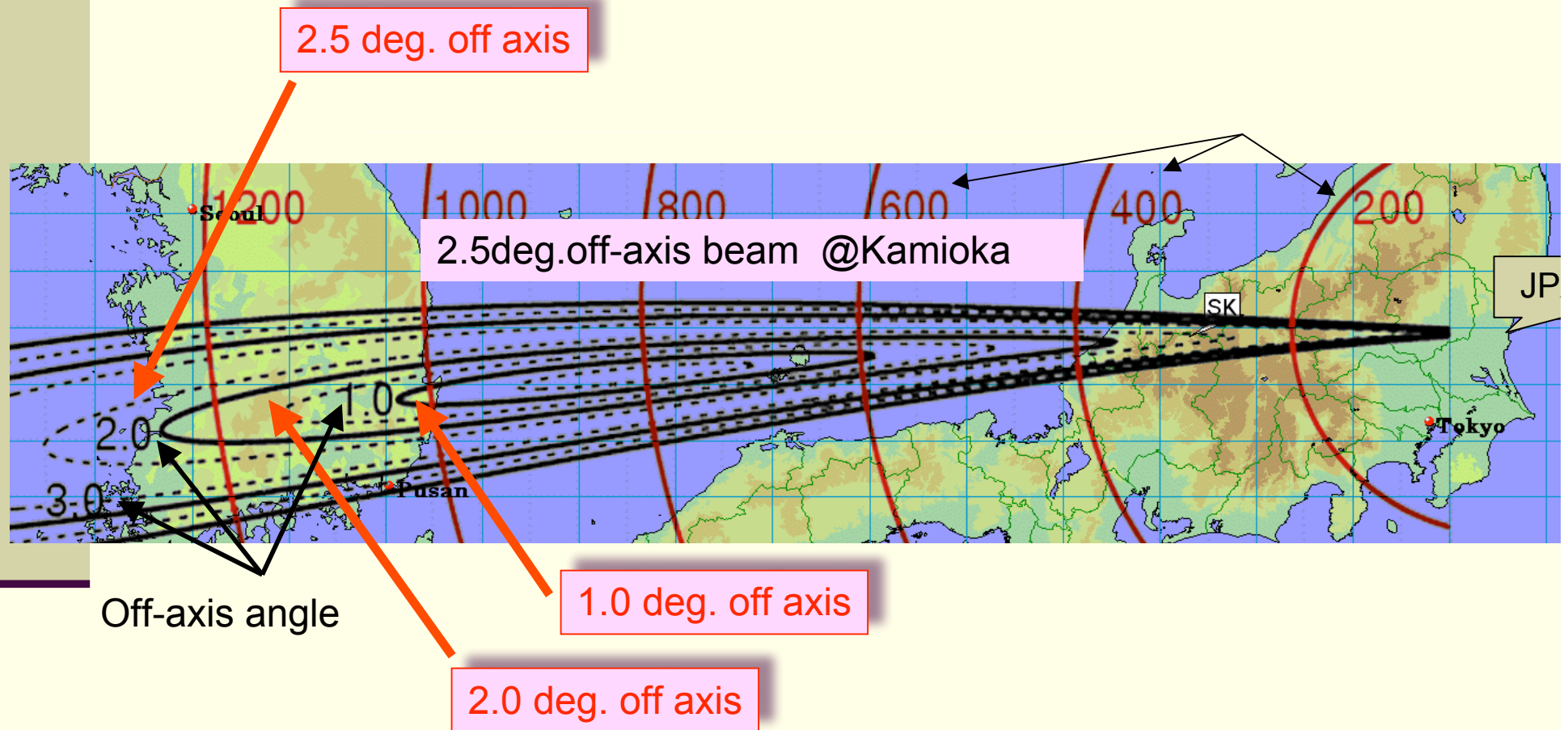
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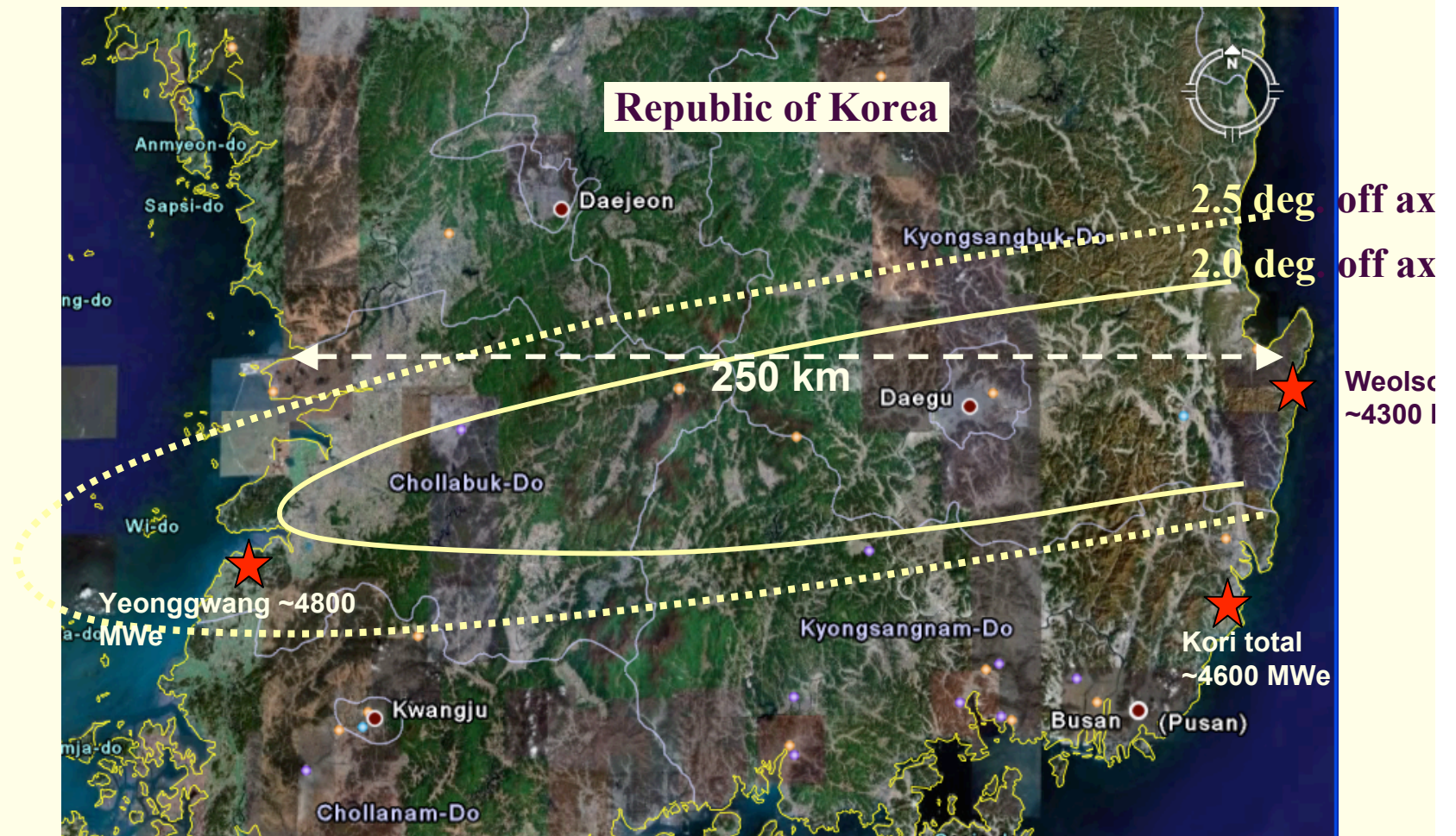
Requirements

- Off-axis angle: **1.0, 2.0, 2.5 degree** ... off-axis beam
- Depth: **~ 1,000 m** (uniform overburden in all direction)
- Underground cavern: 50 m (dia.) x 280 m (l) for underground research module (cylindrical shape)
- Long term safe operation
- Effective (economic) construction
- Research module in good rock mass

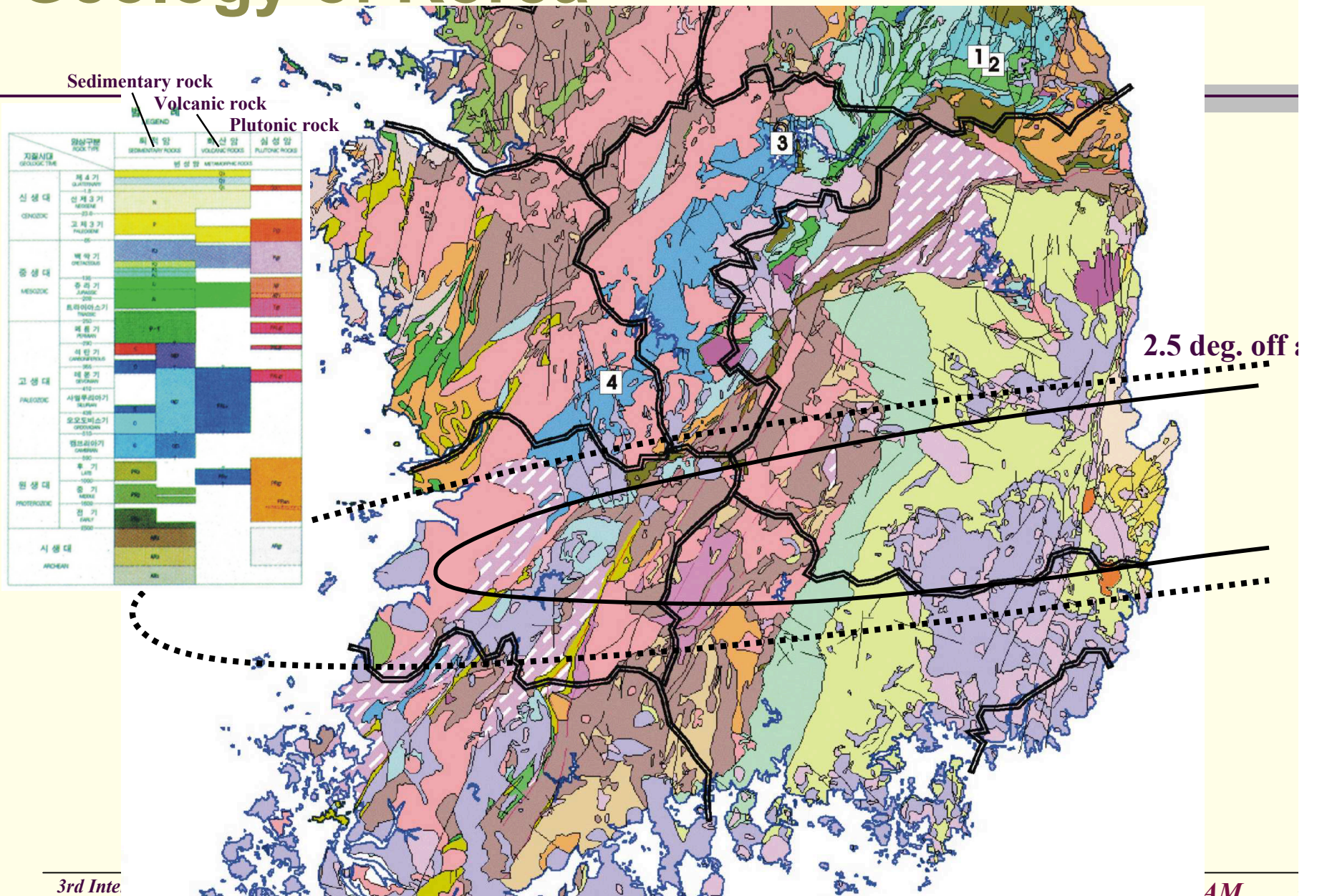
Requirements_Location



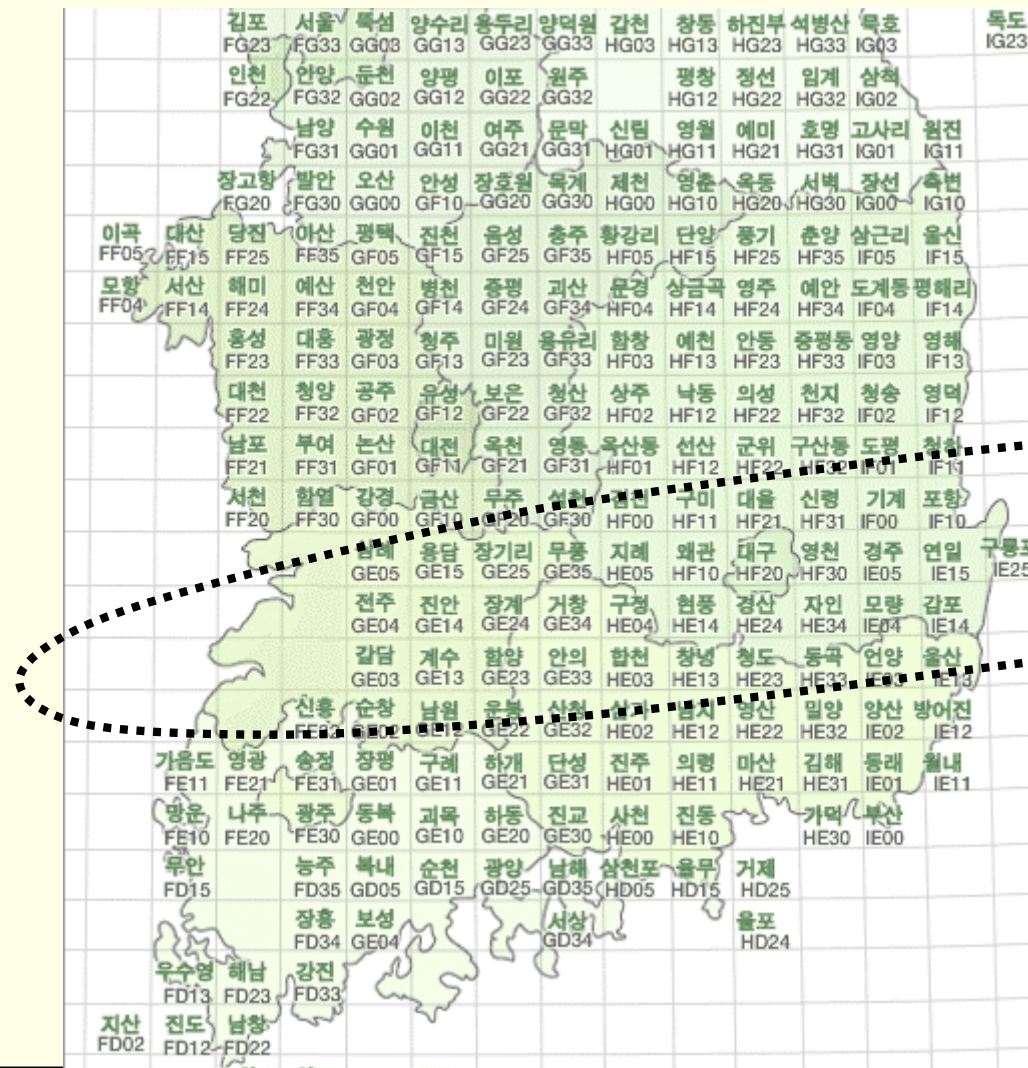
Site Consideration_Off-axis beam line



Geology of Korea



Geological Sheets



2.5 deg. off axis

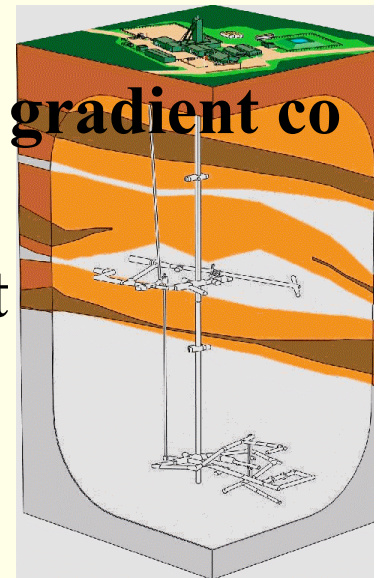
Overview of General Geology

- Throughout the country, **mountains** are not high, rarely exceeding 1,200 meters, but they are found **almost everywhere**. The terrain is rugged and steep, and only near the west and southwest coasts are extensive flat alluvial or diluvial plains and more subdued rolling hilly lands.
- Korea consists largely of the **Precambrian rocks**, such as granite gneisses and other metamorphic rocks. The **Gyeongsang Supergroup** is distributed across a wide area within the Gyeongsang-do province which is one of the area of our concerns.
- The **Gyeongsang Supergroup** is composed of the Sindong and Hwayang groups and the Bulguksa Intrusives. The biotite granite intruded in the Gyeongsang Supergroup is called **Bulguksa Granite**.
Hwayang Group widely distributed throughout the Gyeongsang-do province, consists of conglomerates, sandstone, shale, and volcanic rock such as **andesite, basalt, rhyolite, and tuff**, especially in the upper part of the group.

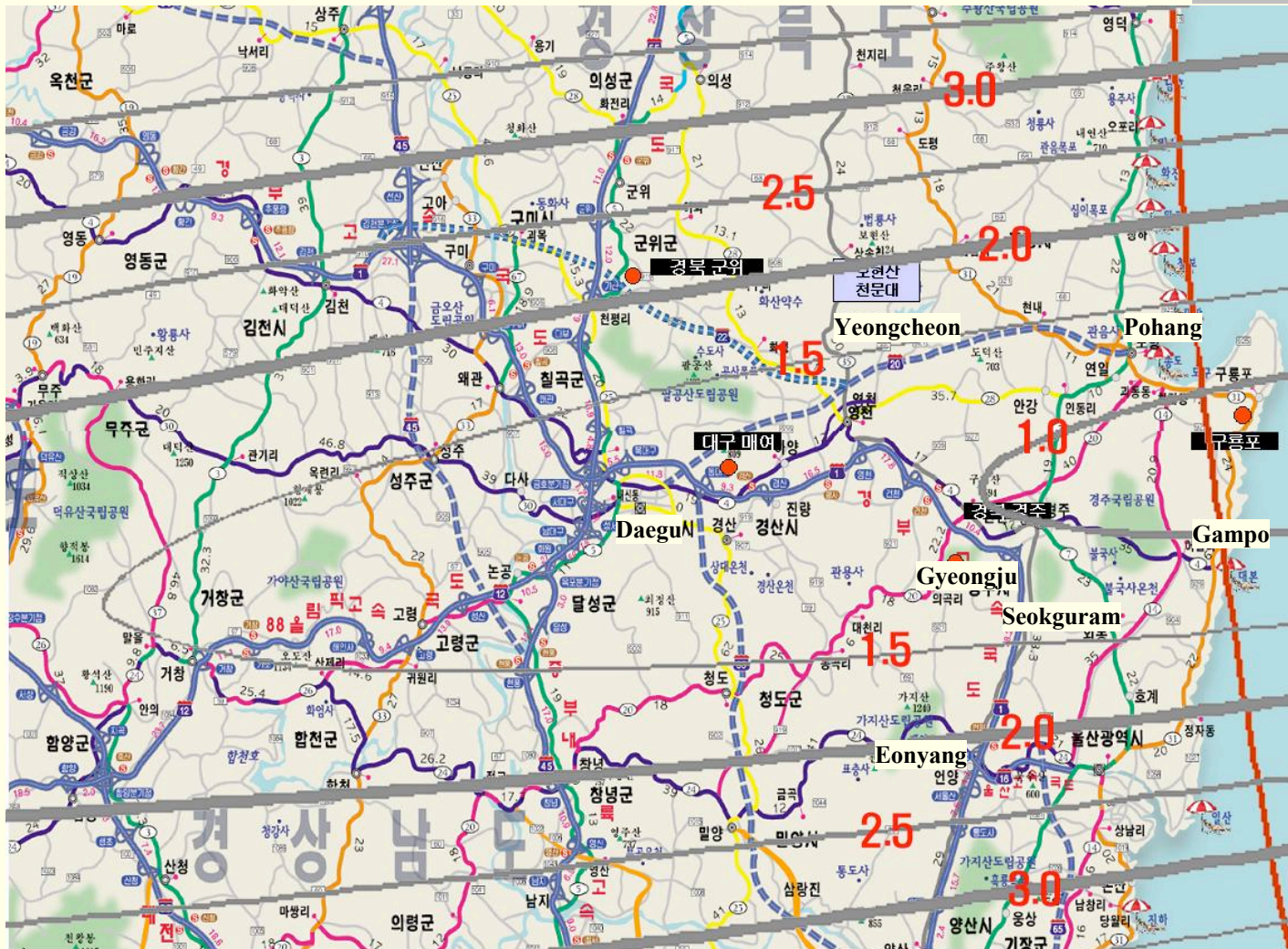
Site Consideration_Depth

- Overburden: **1 km** deep
- **Preferable site:** mountain, mine, tunnel
- Easy slope topography requires
 - excavation of long access tunnel to satisfy gradient condition
 - construction of shaft and/or inclined shaft

too costly !

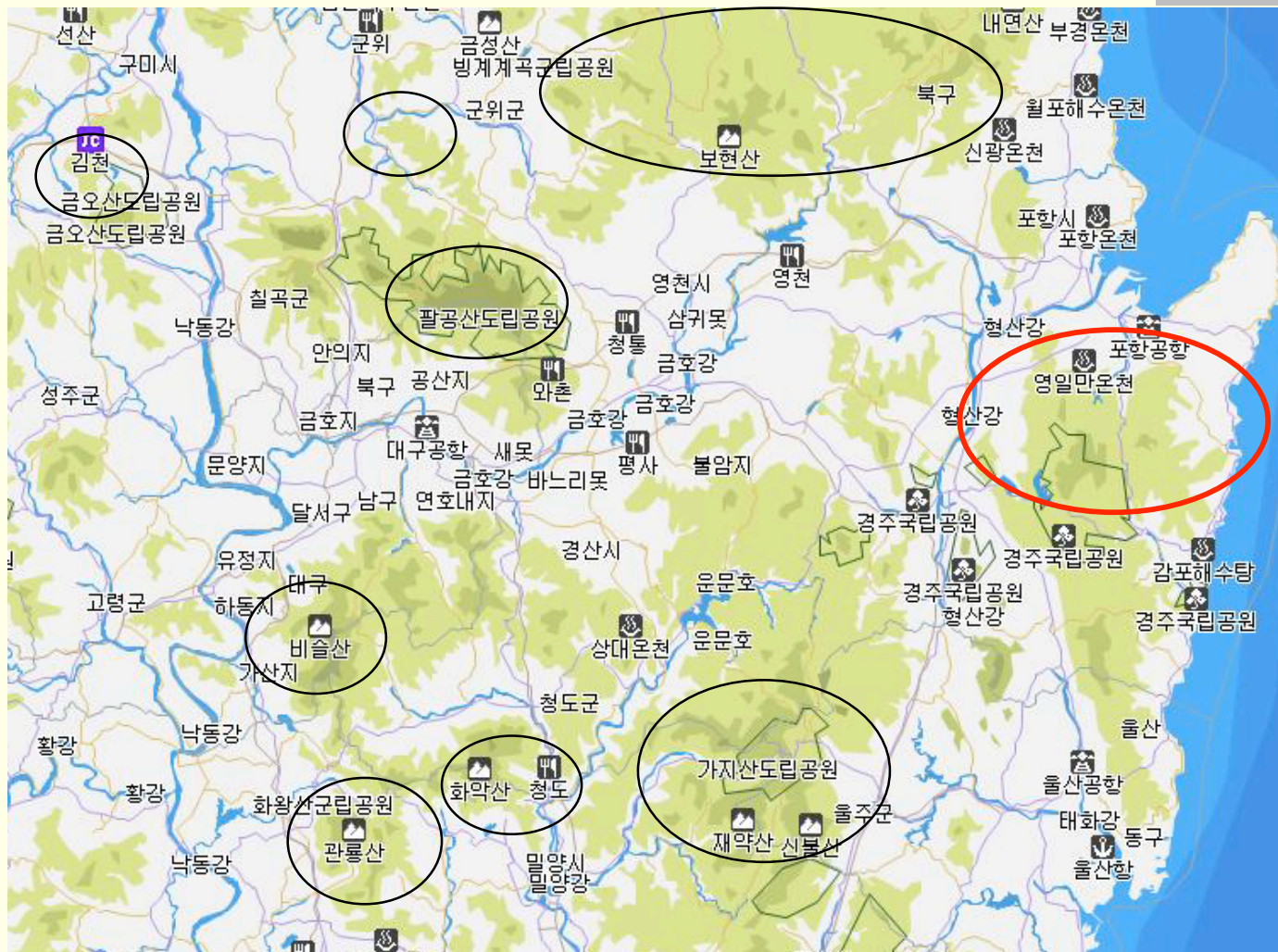


Site Consideration

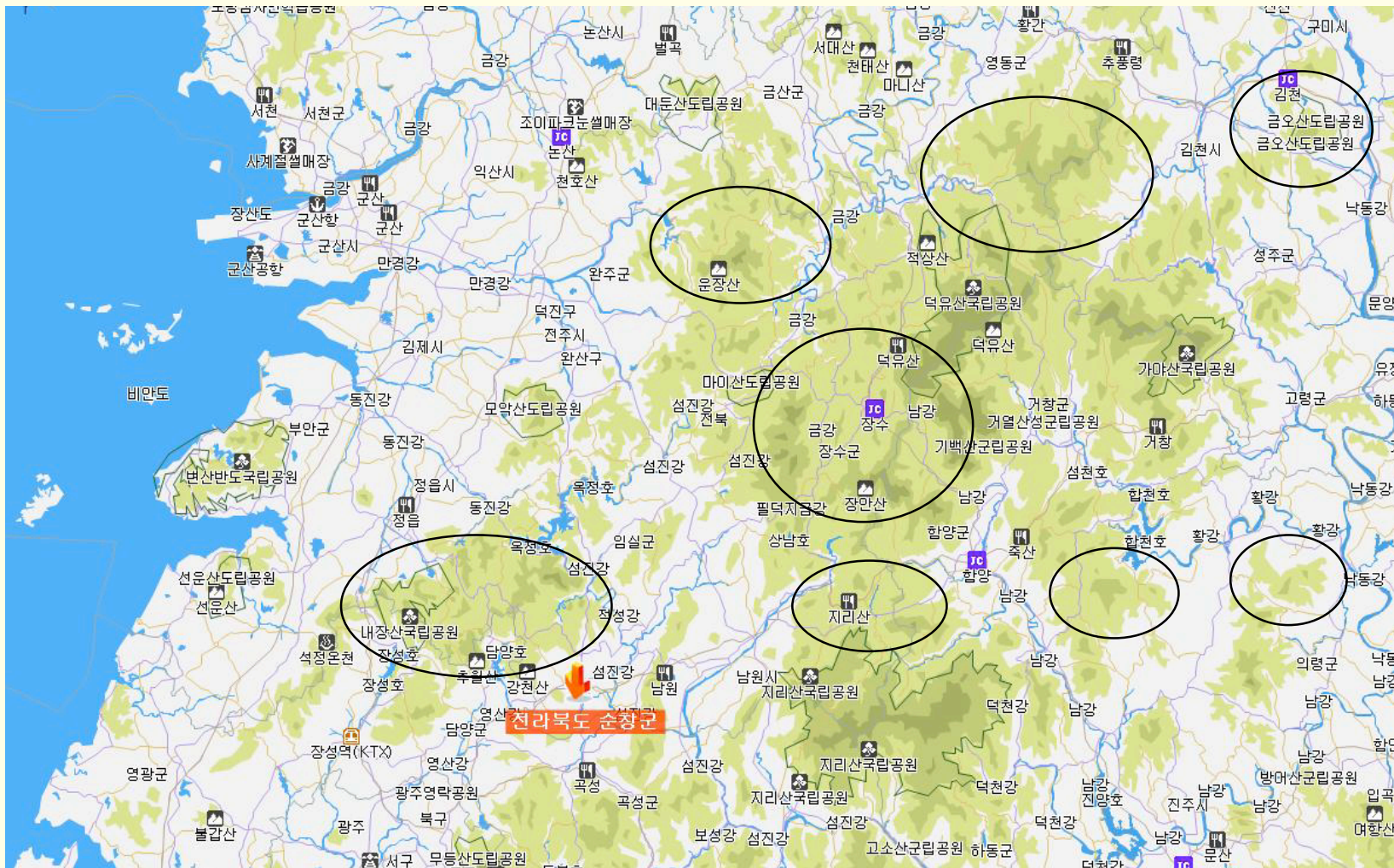


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Possible Sites

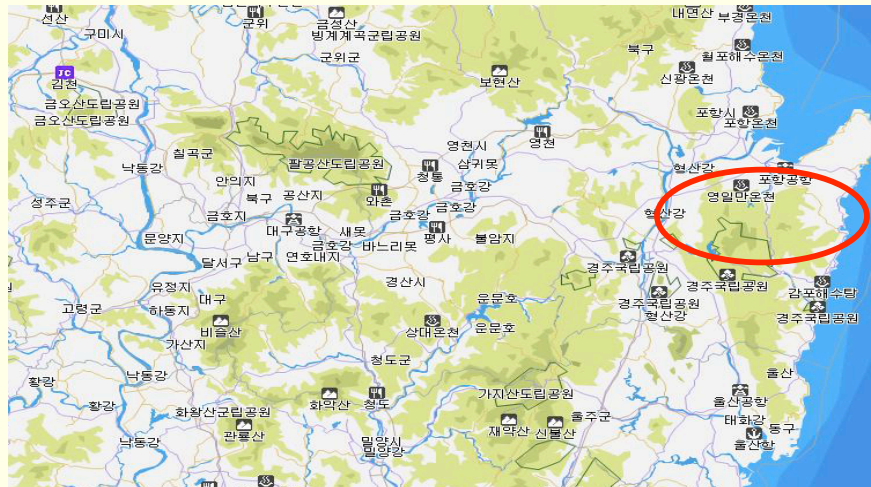


Possible Sites



Site Consideration

- **Guryongpo in Pohang (Gyeongbuk Province)**
 $< 1,000$ km
 $< 1.0^\circ$ off, no mountains (sea level)
- **Toham San in Gyeongju**
 $1,000$ km
 1.0° off, ~ 500 m high mountains (**National Park area**)

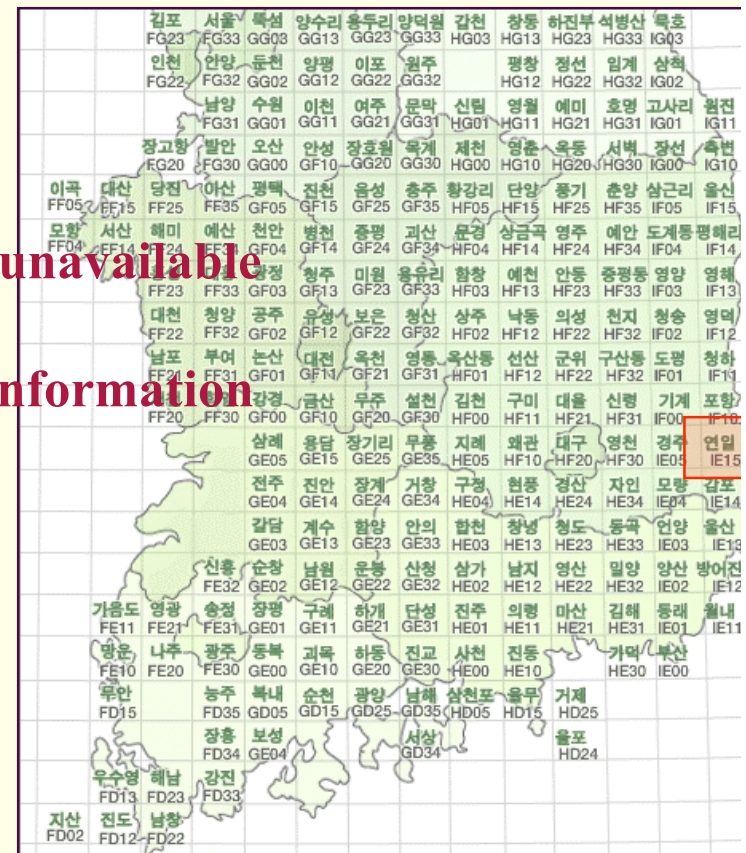


Geology

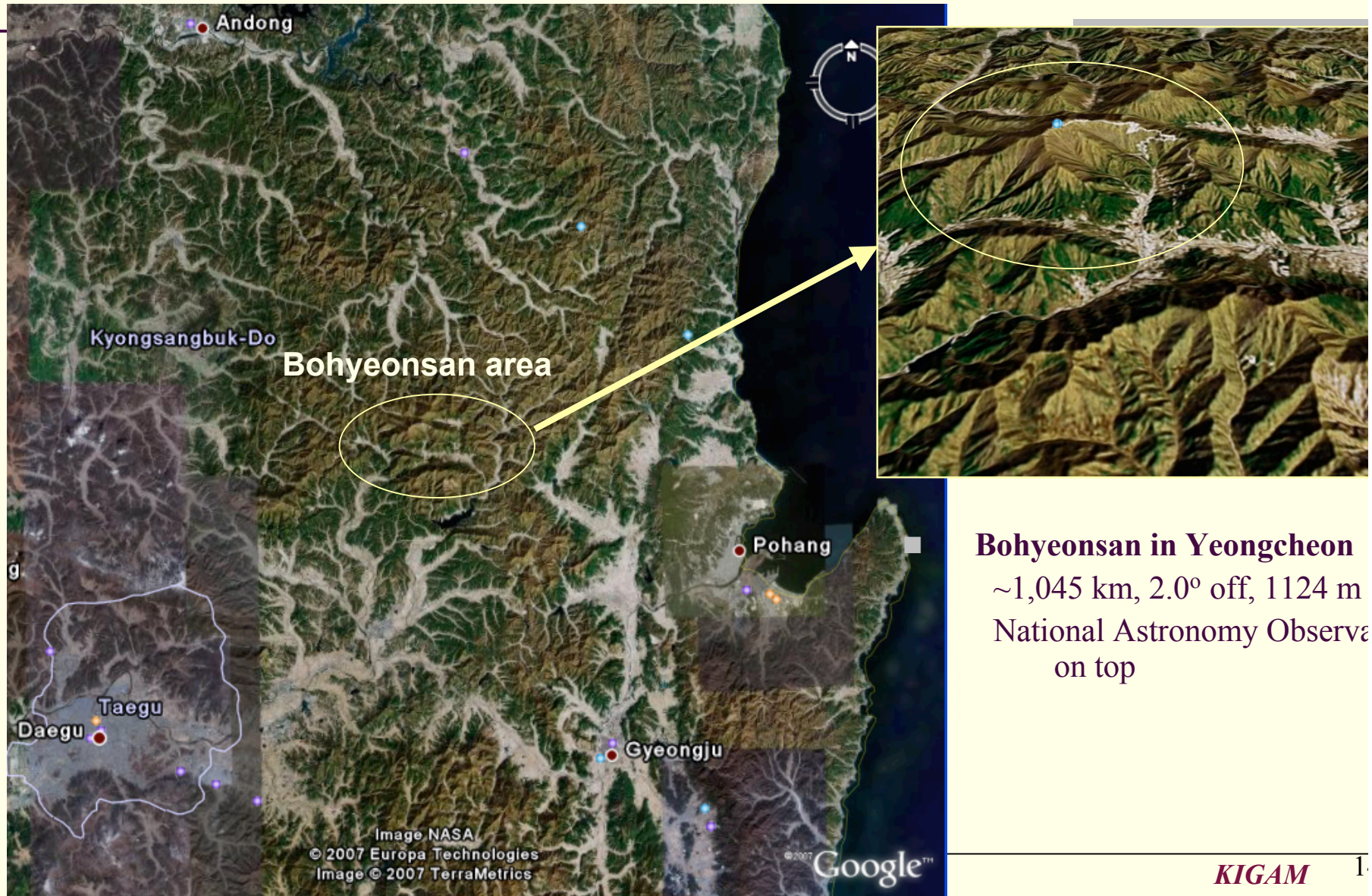
Geological map – Guryogpo/Yeonil Sheet

- ❖ <1 degree off-axis
- ❖ 1:50,000 geological maps of these area: **unavailable**
- ❖ Geological data and some detailed site information **available**

high speed rail way construction
roadway construction



Site Consideration



Bohyeonsan in Yeongcheon
 ~1,045 km, 2.0° off, 1124 m
 National Astronomy Observa
 on top

Description of Geology

GI GAE Sheet:

Southern marginal portion of the Taebaek Mountain Range;

includes the peaks of

Giryongsan (961m),

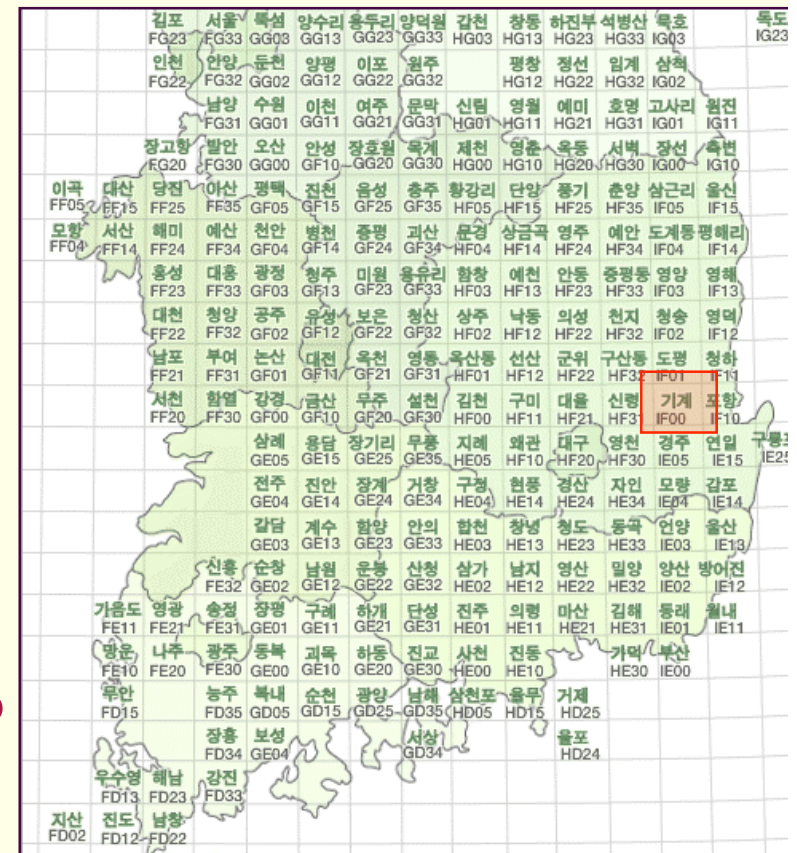
Bohyeonsan (1,124.4m),

Suseokbong (820m),

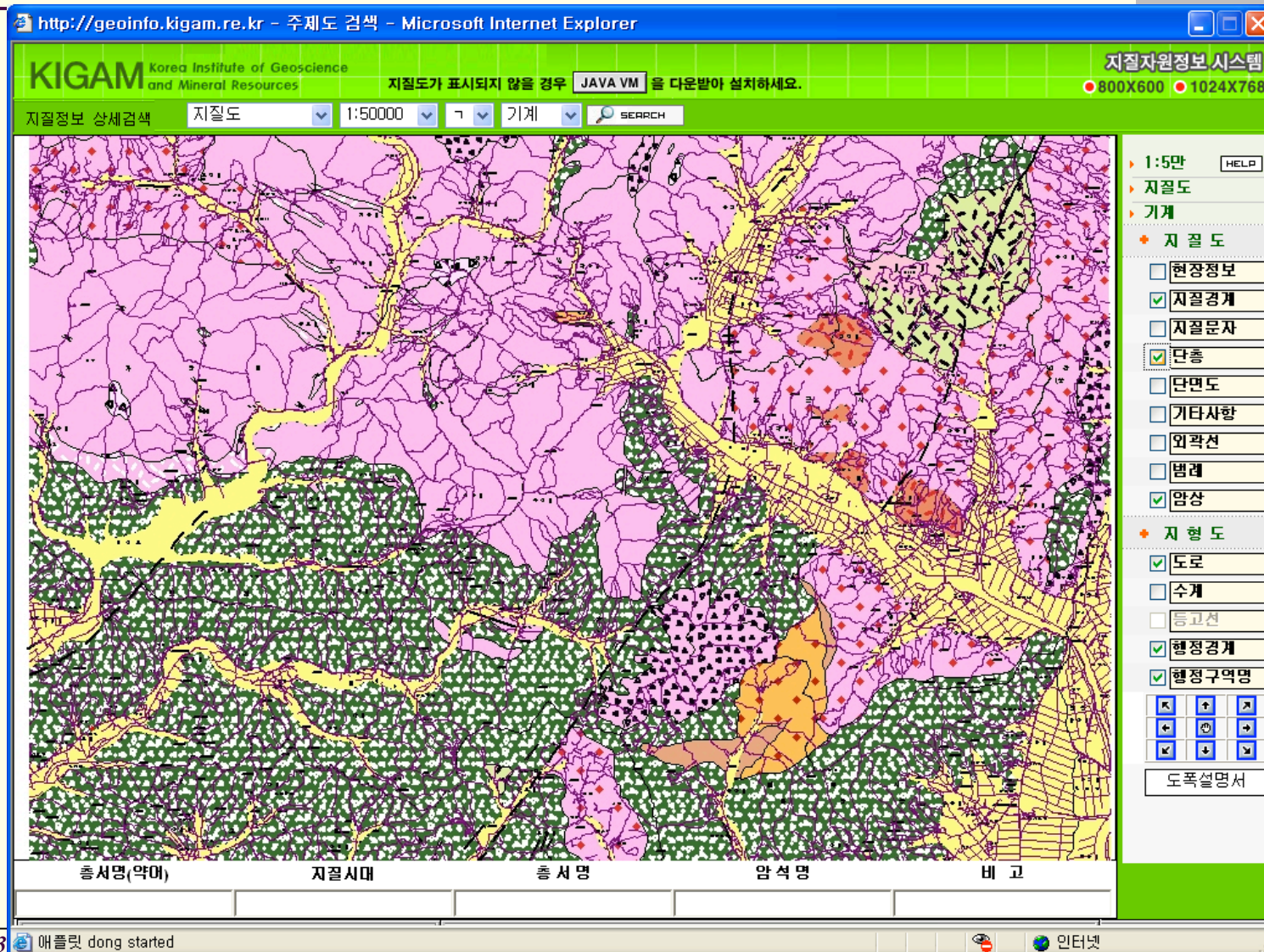
Chimgoksan (725m),

Unjusan (807m);

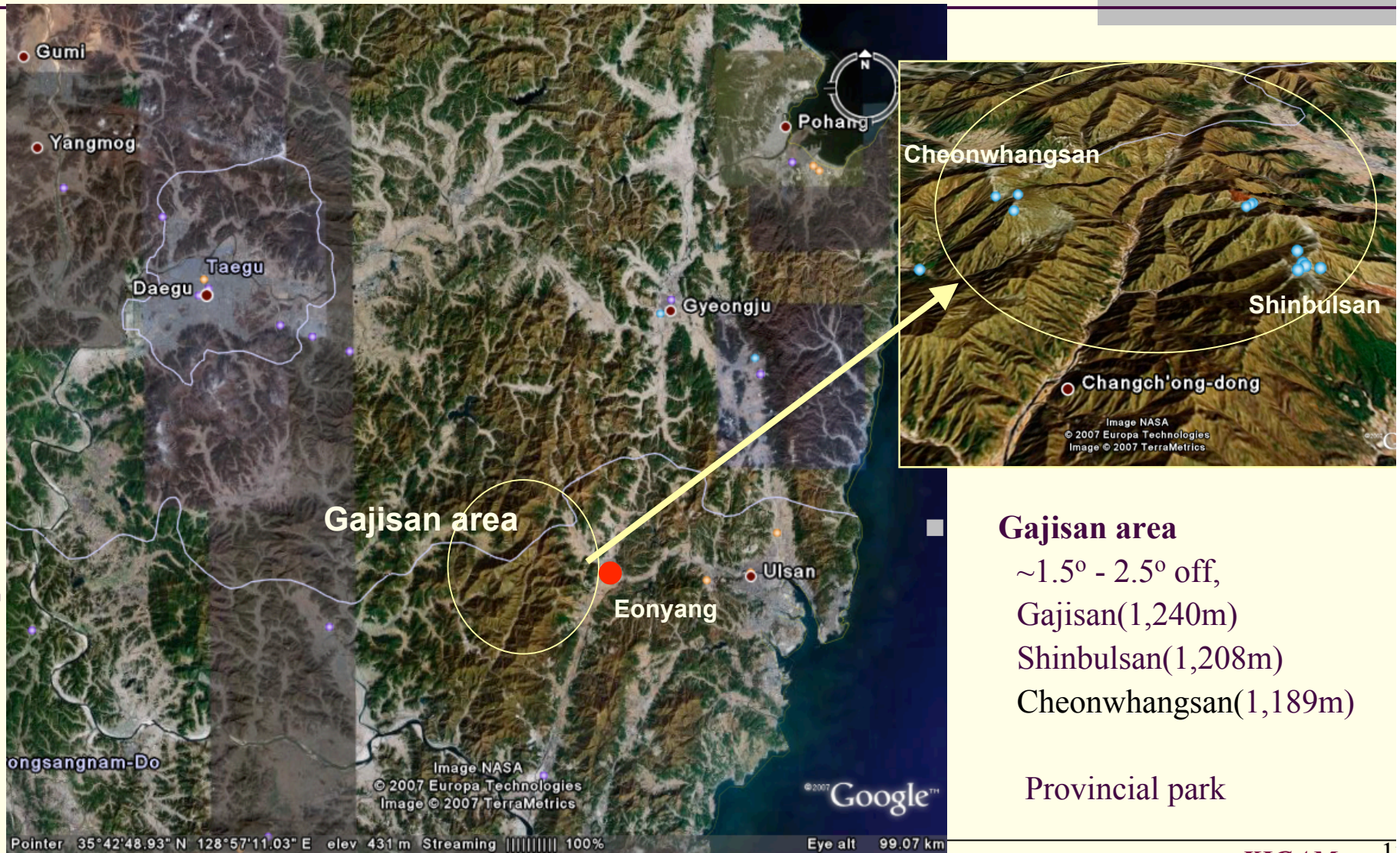
The area is underlain by Cretaceous sedimentary, volcanic and plutonic rocks - **granite, granodiorite, andesite, rhyolite** ...



Geological map of GI GAE sheet _1:50000



Site Consideration



Gajisan area

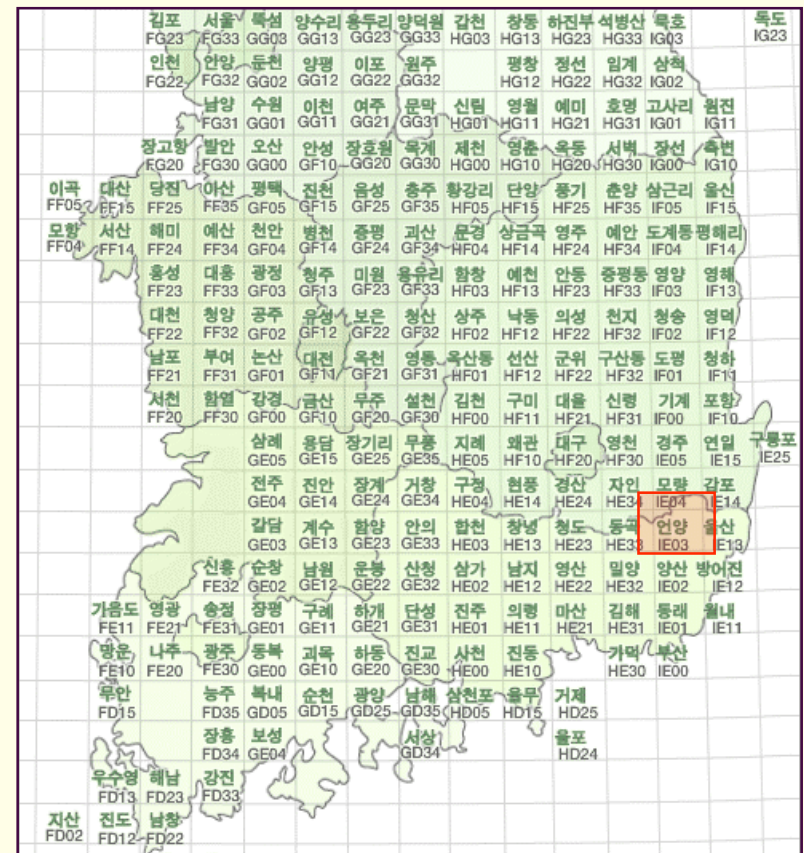
~1.5° - 2.5° off,
Gajisan(1,240m)
Shinbulsan(1,208m)
Cheonwhangsansan(1,189m)

Provincial park

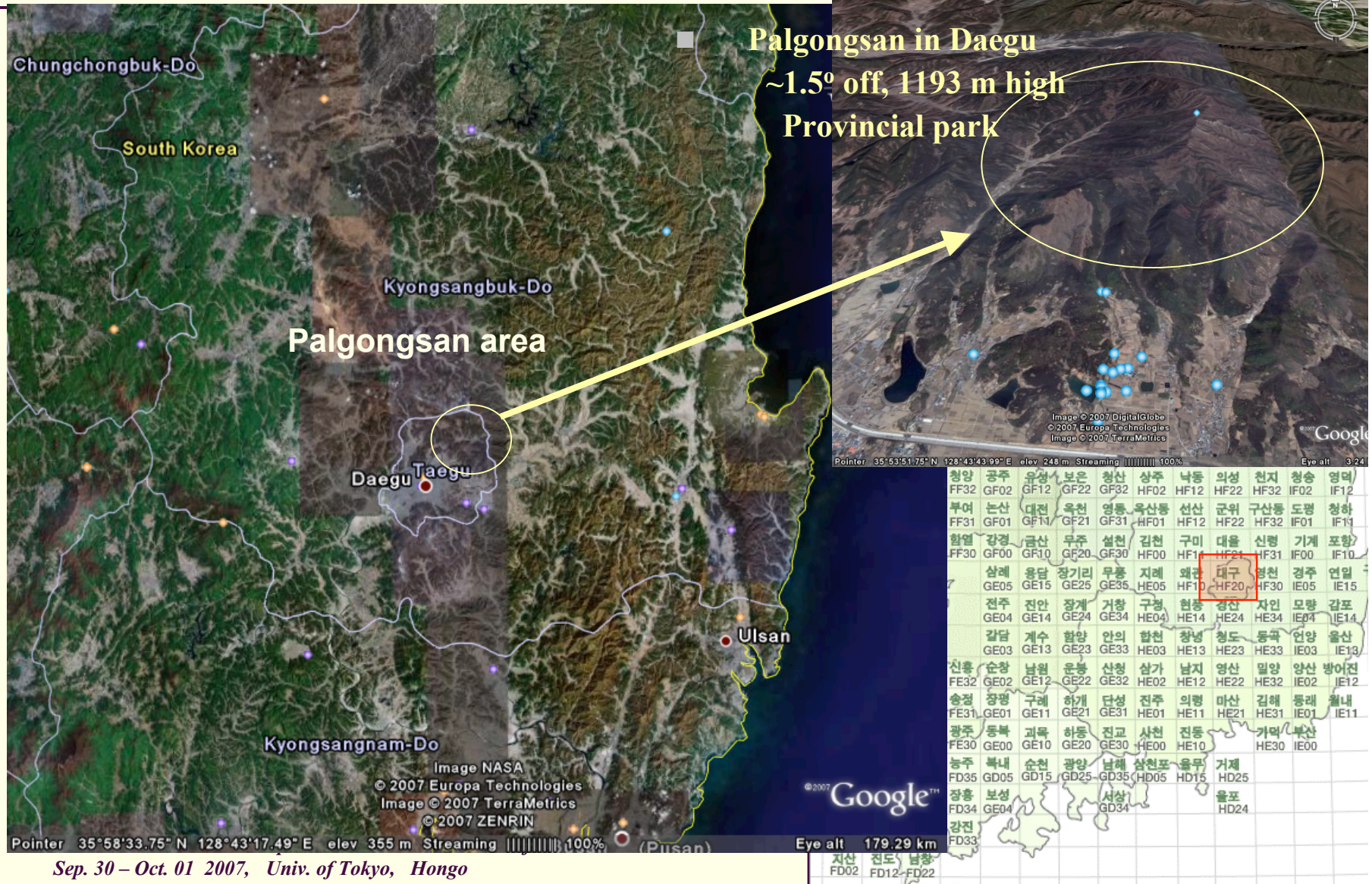
Description of Geology

EON YANG Sheet:

High mountainous districts in cludes the peaks of **Gajisan**(1 240m), **Shinbulsan**(1208m), in the western part, underlain by **andesite**, **granite**, and other rocks



Site Consideration



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Other Sites

SHINSHEUNG Sheet:

Noryeong mountain range, many peaks attain heights of between 400-760m; **Sinseon-bong**(763m)
Gneiss, granite, sedimentary and volcanic rocks

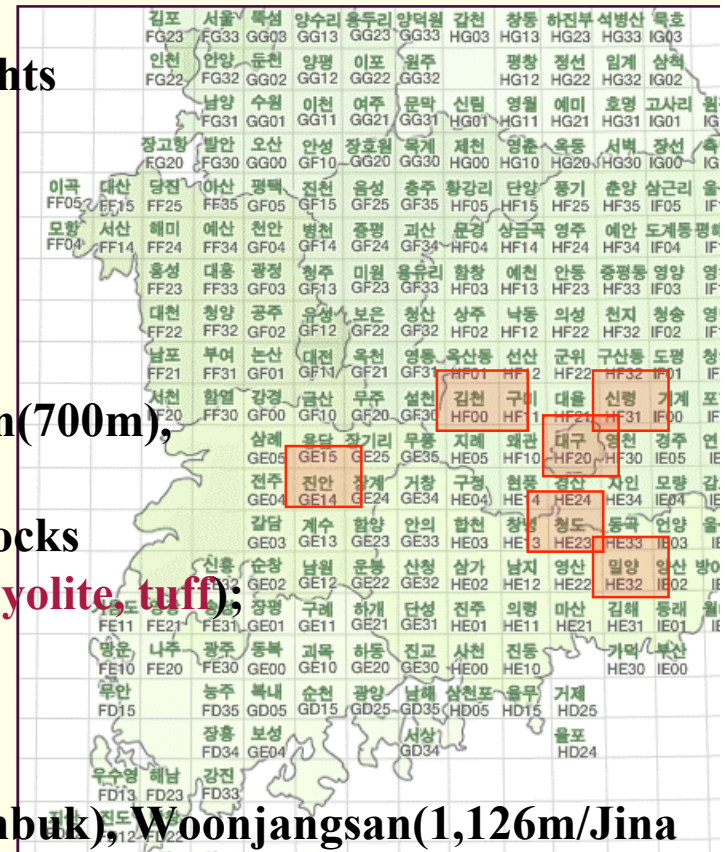
MIRYANG Sheet

There are comparatively high **peaks** of
Togoksan(855m), Yomsubong(816m), Muchoksan(700m),
Hyangrobong(727m), Manosan(670m) etc.

Geology: Yuchon Group and Bulguksa Intrusive rocks
-andesitic rocks (**andesite, tuff**), rhyolitic rocks (**rhyolite, tuff**);
Miryang **andesite** is distributed on a large scale.

Other Sheets

Bisulsan(1,084m/Daegu) Jangansan(1,237m/Cheonbuk), Woonjangsan(1,126m/Jina n), Whaaksan(938m/Cheongdo)
Gumosan(977m/Gumi) ...



Mine Site

Advantages of utilizing abandoned/closed mine

- ✓ **Reduce costs**
- ✓ **Minimize environmental impacts**
- ✓ **Minimize complaints from residents and
environmentalist**
- ✓ **Easy to get approval and
to get support from local government**
- ✓ **Easy to get information on geological conditions**

Mines

Abandoned Mines

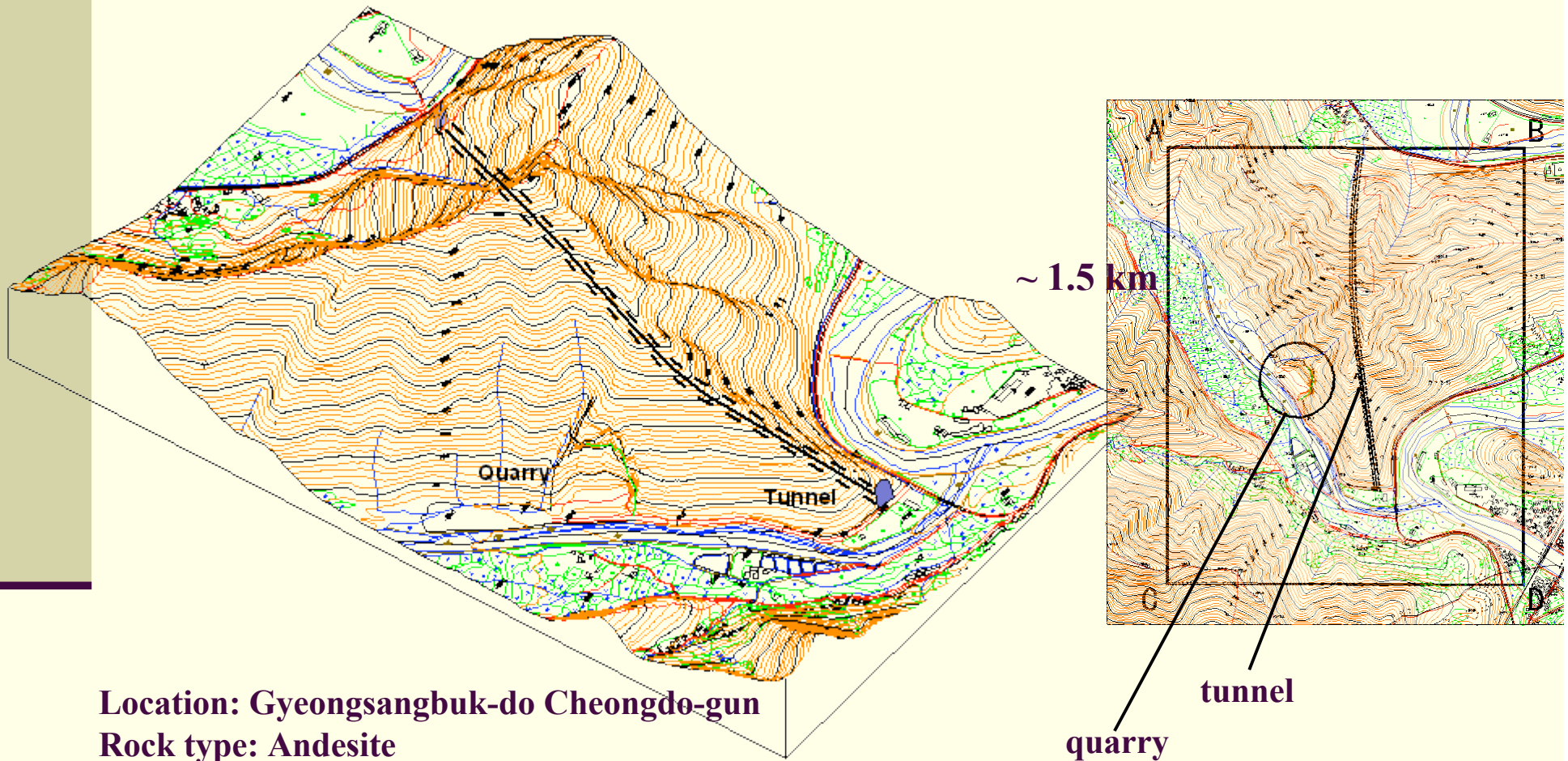
Province	Coal mine				Metal, Non-metal mine			
	A	B	C	D	A	B	C	D
Gangwon-do	5	1	3	5	6		7	3
Gyeonggi-do					1		2	2
Chungbuk-do							4	4
Chungnam-do	8			3	1			
Jeonnambuk-do					2			2
Gyeongbuk-do	1			1			4	1
Gyeongnam-do					1		1	

* Possibility of utilization: $A > B > C > D$

(source: KIGAM report, 2004)

Useful ?

Abandoned Quarry near Miryang



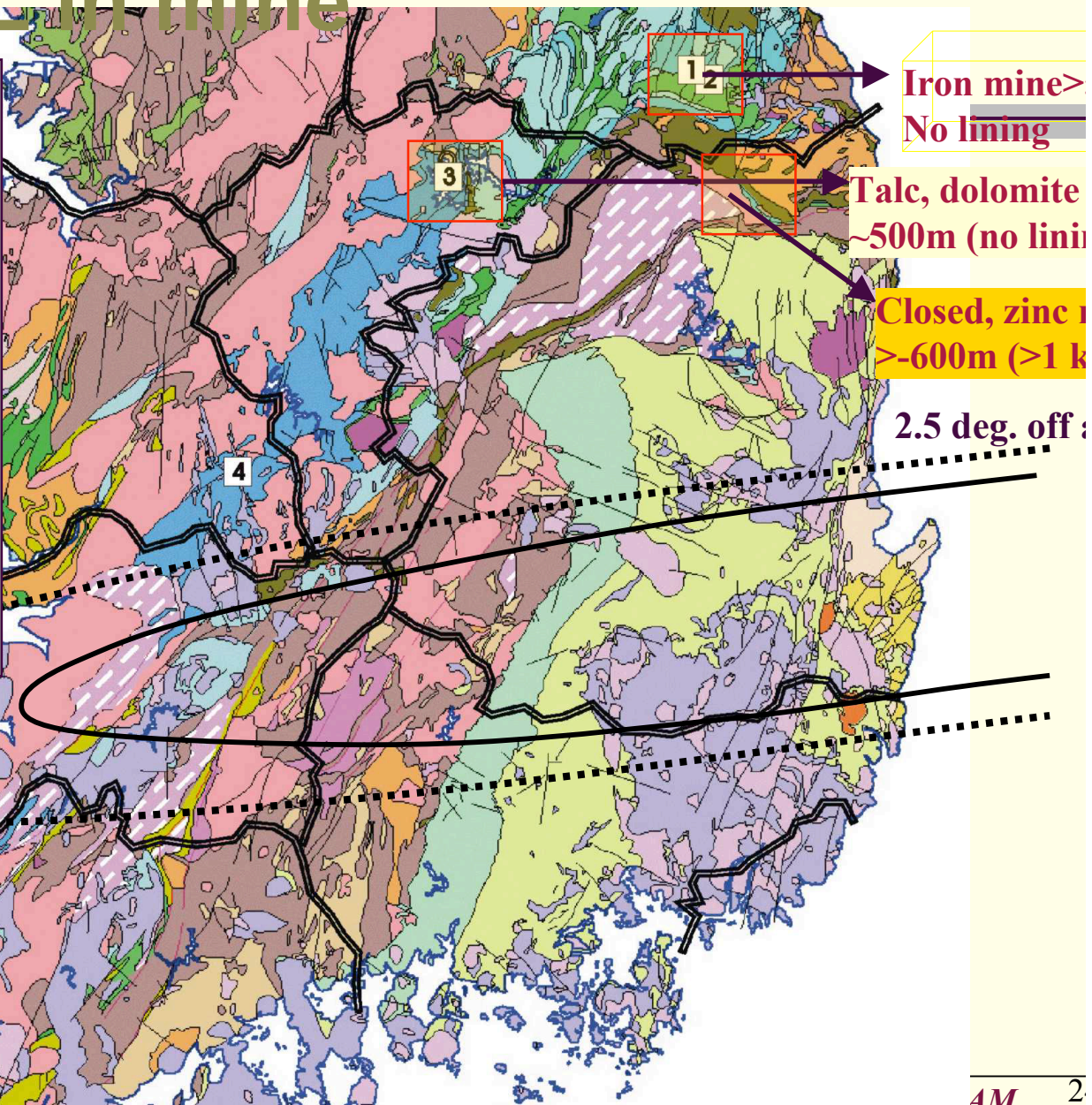
Location: Gyeongsangbuk-do Cheongdo-gun

Rock type: Andesite

Uni-axial compressive strength: 1,500 ~ 1,600 kgf/cm²

KIGAMs URL in mine

김포	서울	북성	안수리	용두리	양덕리	갑천	창동	하진부	석방산	북호	북도
FG23	GG33	GG09	GG13	GG23	GG33	HG03	HG13	HG23	HG33	IG03	IG23
인천	안양	둔천	양평	이포	원주	평창	정선	임계	삼척		
FG22	GG32	GG02	GG12	GG22	GG32	HG11	HG22	GG32	IG02		
남양	수원	이천	여주	문막	신원	영월	홍성	고사리	원전		
FG31	GG01	GG11	GG21	GG31	HG01	HG11	HG21	IG01	IG11		
장고항	팔안	오산	안성	장호원	목계	재천	원주	석백	장선	죽변	
FG20	FG30	GG00	FG10	GG20	GG30	HG00	HG10	HG20	HG30	IG00	IG10
이곡	대산	당진	아산	평택	진천	음성	충주	황강리	단양	통기	춘양
FF05	FF15	FF25	FF35	FF05	FF15	FF25	FF35	IF05	IF15	IF25	IF35
모항	서산	해미	예산	천안	병천	충령	괴산	문경	상금곡	영주	예산
FF04	FF14	FF24	FF34	FF04	FF14	FF24	FF34	IF04	IF14	IF24	IF34
홍성	대동	공정	청주	충청	충청	충청	충청	충청	충청	충청	충청
FF23	FF33	FF03	FF13	FF23	FF33	FF03	FF13	FF23	FF33	FF03	FF13
대전	청양	공주	유성	보은	청산	상주	남동	의성	천지	청송	영덕
FF22	FF32	FF02	FF12	FF22	FF32	FF02	FF12	FF22	FF32	FF02	FF12
남포	부여	논산	대천	유천	영동	육산동	선산	군위	구산동	도령	청하
FF21	FF31	FF01	FF11	FF21	FF31	FF01	FF11	FF21	FF31	FF01	FF11
서천	함열	강경	금산	무주	설천	김천	구미	대동	신령	기계	포항
FF20	FF30	FF00	FF10	FF20	FF30	FF00	FF10	FF20	FF30	FF00	FF10
삼례	용담	장기리	무룡	지례	왜관	대구	영천	경주	연일	구룡포	IE25
GE05	GE15	GE25	GE35	GE05	GE15	GE25	GE35	IE05	IE15	IE25	
전주	진안	장계	거창	구령	현종	경산	자인	모항	강포		
GE04	GE14	GE24	GE34	IE04	IE14	IE24	IE34	IE04	IE14		
김남	계수	함양	안의	함진	창녕	청도	동곡	임양	울산		
GE03	GE13	GE23	GE33	IE03	IE13	IE23	IE33	IE03	IE13		
신용	순창	남원	온성	산청	삼가	남지	영산	밀양	양산	방어진	
FE32	FE02	FE12	FE22	FE32	FE02	FE12	FE22	FE32	FE02	FE12	
가음도	영광	송정	장평	구례	단성	진주	의령	마산	김해	동래	철내
FE11	FE21	FE31	FE01	FE11	FE21	FE31	FE01	FE11	FE21	FE31	FE01
방은	나주	광주	동북	괴곡	하동	진교	사천	진동	거미	부산	
FE10	FE20	FE30	FE00	FE10	FE20	FE30	FE00	FE10	FE20	FE30	FE00
무안	봉성	광양	남해	삼천포	울주	거제					
FD15	FD35	GD05	GD15	GD25	GD35	HD05	HD15	HD25			
무수영	해남	강진									
FD13	FD23	FD33									
자산	진도	남향									
FD12	FD22										



Construction_Tunnel & Cavern



General procedure

- Preliminary data collection
 - preliminary assessment
 - preliminary geotechnical characterization

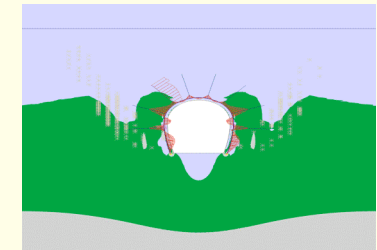
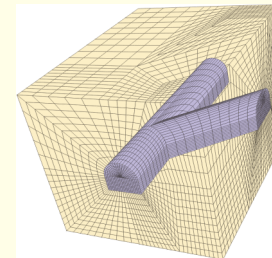
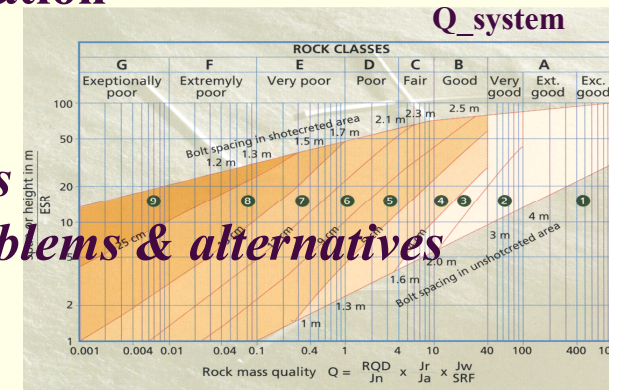
Feedback loop

- Feasibility study
 - *engineering classification of rock mass*
 - *feasibility assessment of tunneling problems & alternatives*

- Detailed site characterization

- Stability analyses

- Final design and construction



Numerical study for cavern stability

Critical Factors_Stability

✓ State of in-situ stress

- orientation, magnitude, stress ratio ...
- ~ depth, geology, topography, lithology ...

✓ Mechanical properties of rock mass

- strength, E , ν ...

✓ Structural characteristics of rock mass

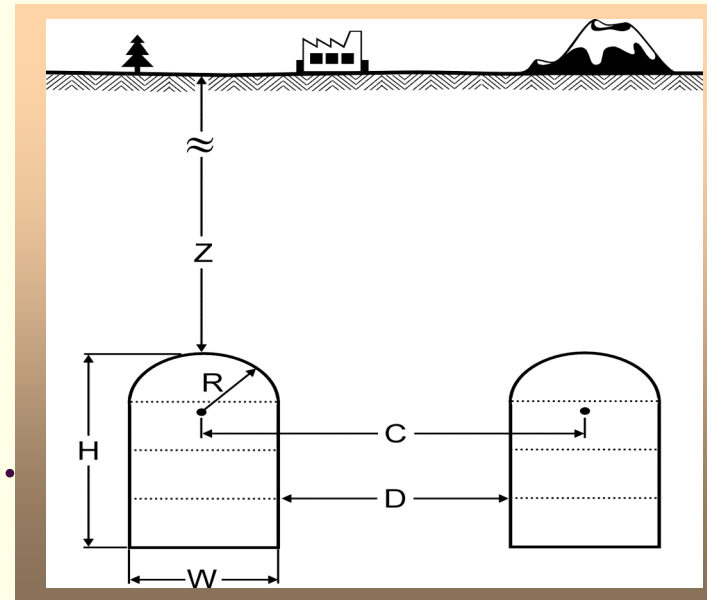
- rock joints: joint distribution, properties ...

✓ Size and shape of cavern and tunnels

✓ Arrangement of cavern and tunnels

- distance between caverns, orientation

✓ Groundwater conditions; Method and quality of excavation ...



Requirements_Long term stability

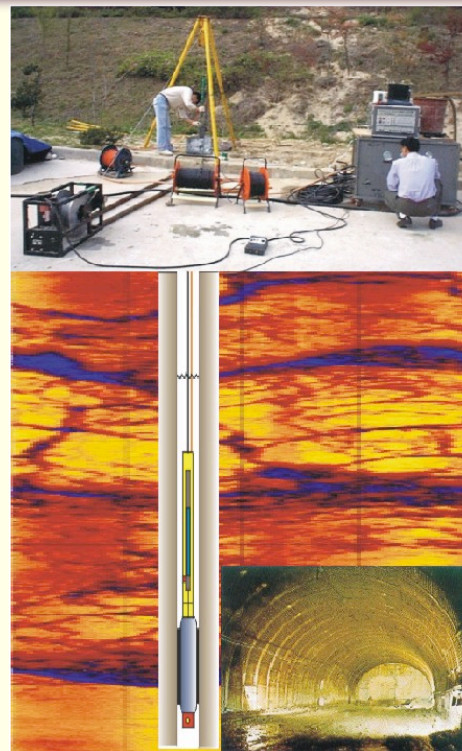
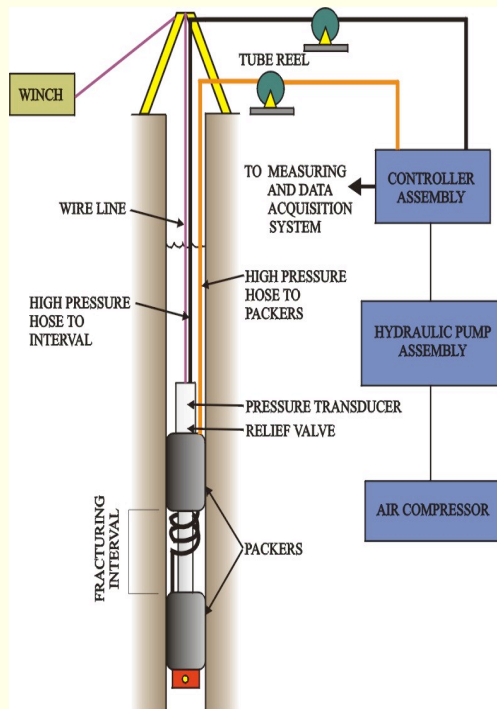
- ◆ Long-term geological stability:
Neotectonics, Volcanism, Seismicity
Uplift/Subsidence, Erosion effect

- ◆ Preferred conditions for a deep geological structure:
 - Homogeneous rock composition
 - Simple geological structure
 - Stable ground water composition

In-situ Stress Measurement

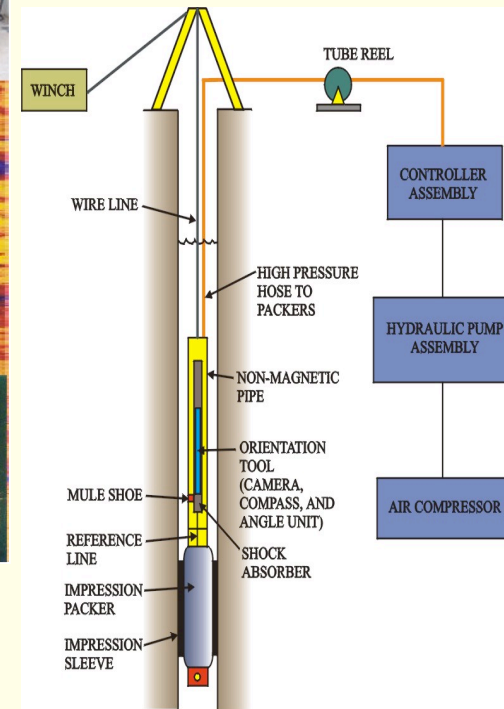
Hydraulic Fracturing System

Borehole fracturing



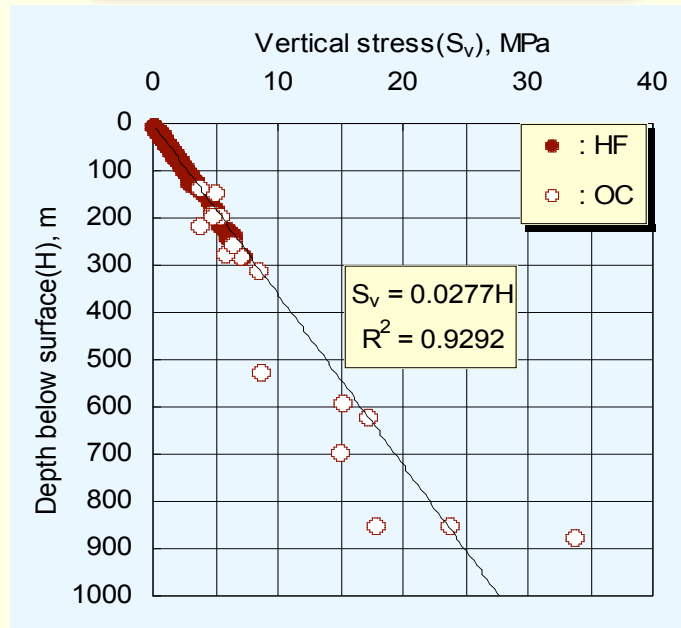
Field test view

Fracture impression

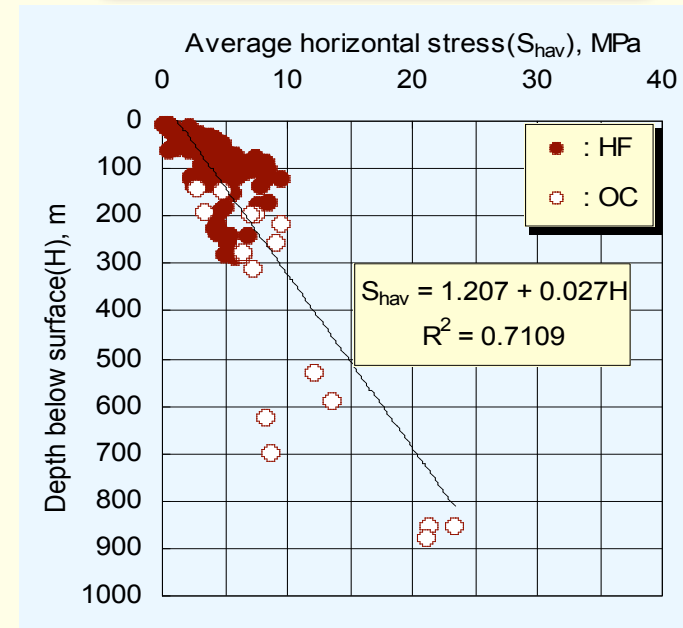


Trend of In-situ Stress in Korea

Vertical stress



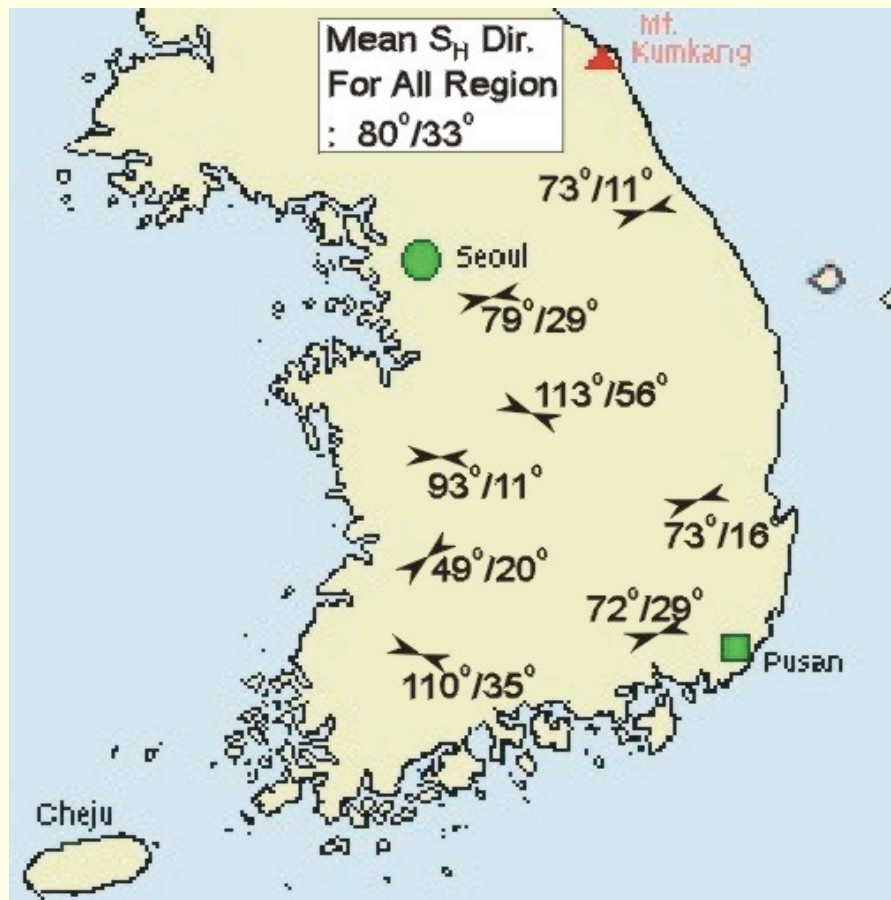
Avg. Horizontal stress



- * Hydraulic fracturing : 41 sites and 156 points for 0~300m depth
- * Over-coring : 15 sites and 18 points for 100~900m depth
- * Linear fitting of stress trend : $S_v = 0.0277H$, $S_{hav} = 1.207 + 0.027H$

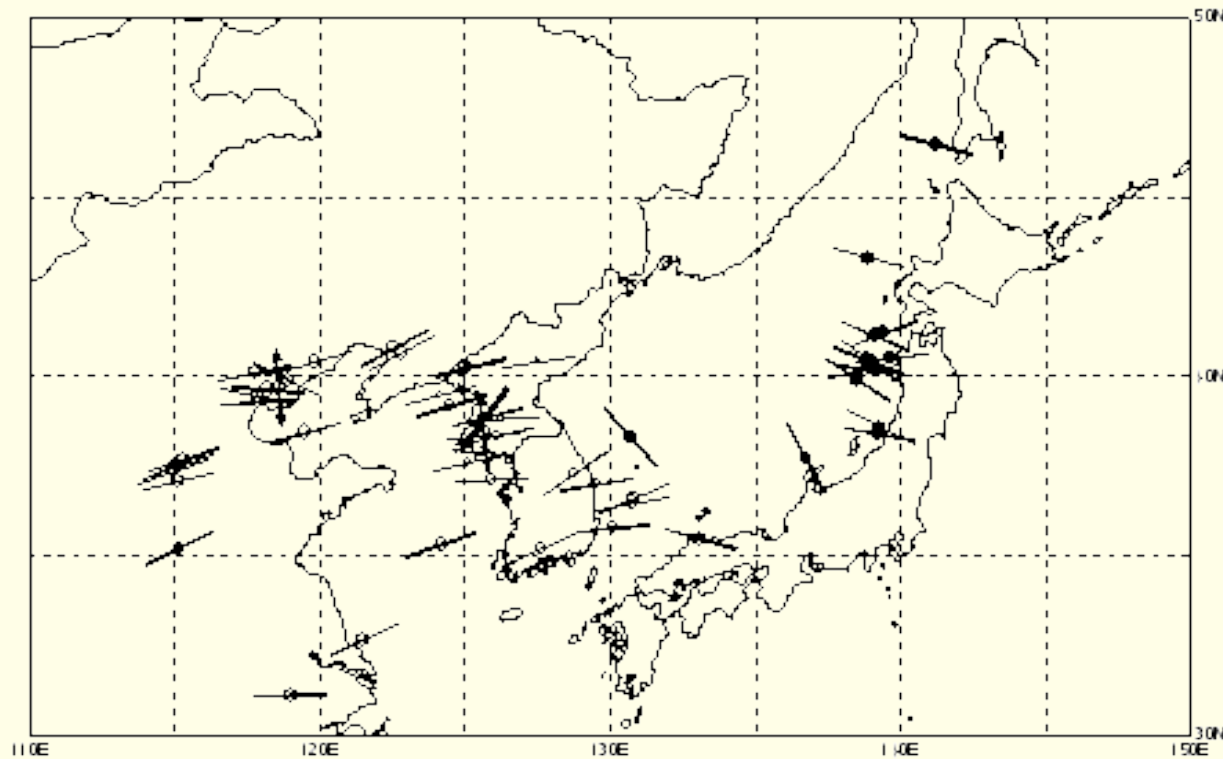
Orientation of In-situ Stress

Direction of max. horizontal stresses measured by hydraulic fracturing

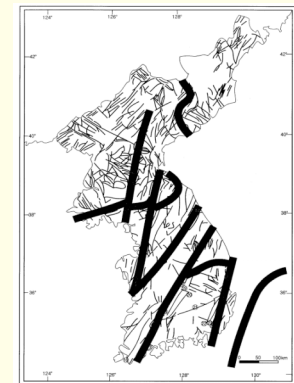


Region	Mean Dir. / S.D.	Depth (m)
Gyeonggi-do	$79^\circ / 29^\circ$	20~180
Gangwon-do	$73^\circ / 11^\circ$	50~140
Chungbuk-do	$113^\circ / 56^\circ$	20~240
Chungnam-do	$93^\circ / 11^\circ$	25~75
Gyeongbuk-do	$73^\circ / 16^\circ$	10~135
Gyeongnam-do	$72^\circ / 29^\circ$	10~290
Jeonbuk-do	$49^\circ / 20^\circ$	15~110
Jeonnam-do	$110^\circ / 35^\circ$	30~95
All Regions	$80^\circ / 33^\circ$	10~290

Orientation of In-situ Stress



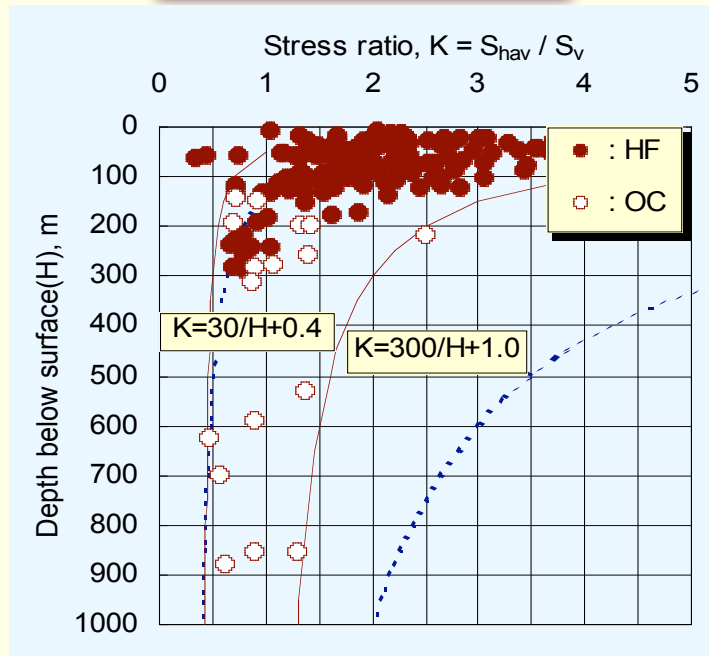
<Stress distribution>



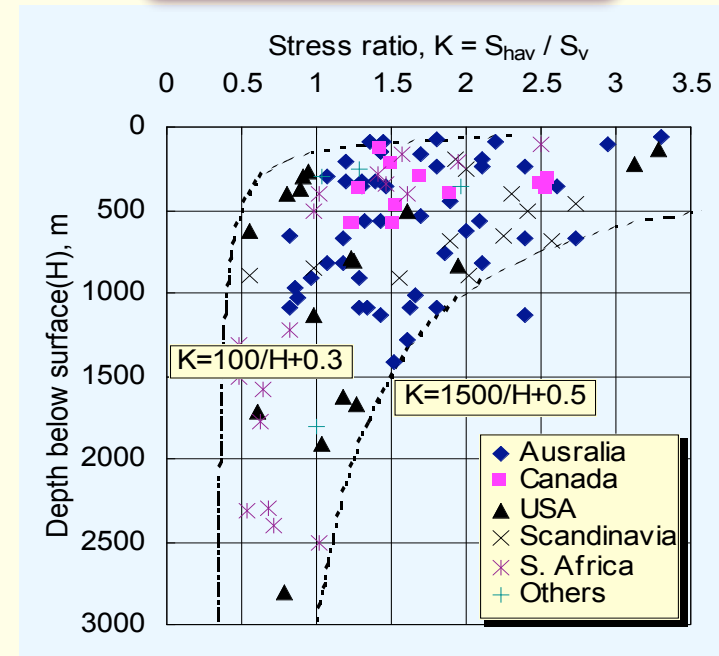
<Neotectonic zones>

Stress ratio, $K = S_{hav} / S_v$

Korea

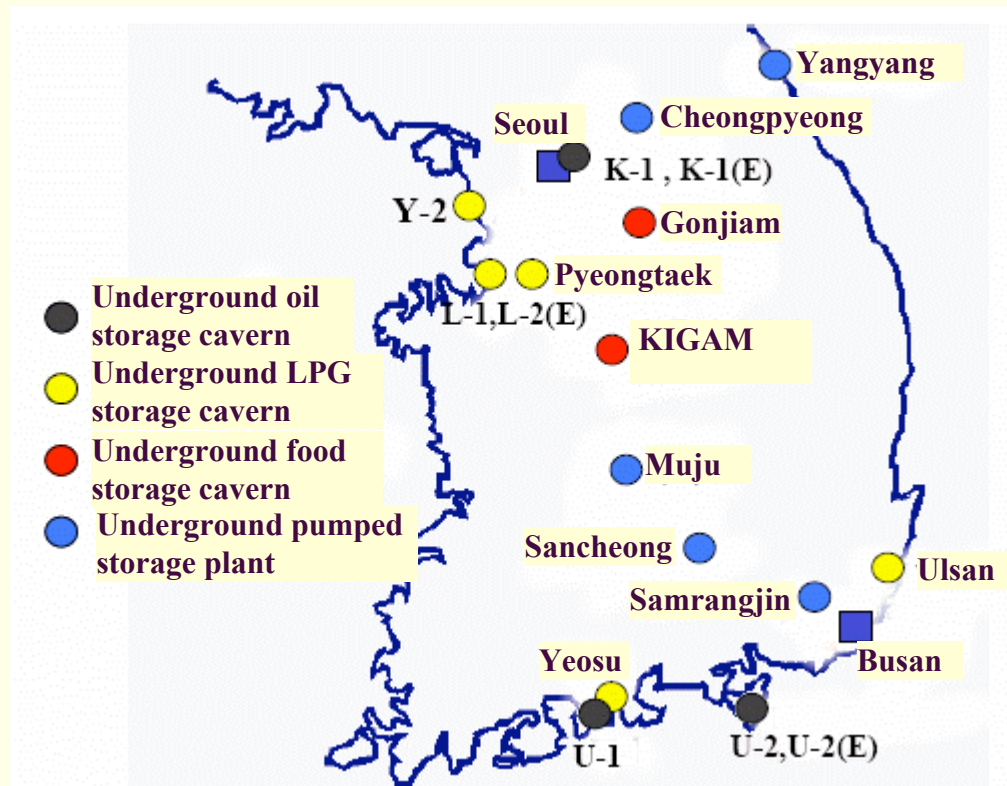


World



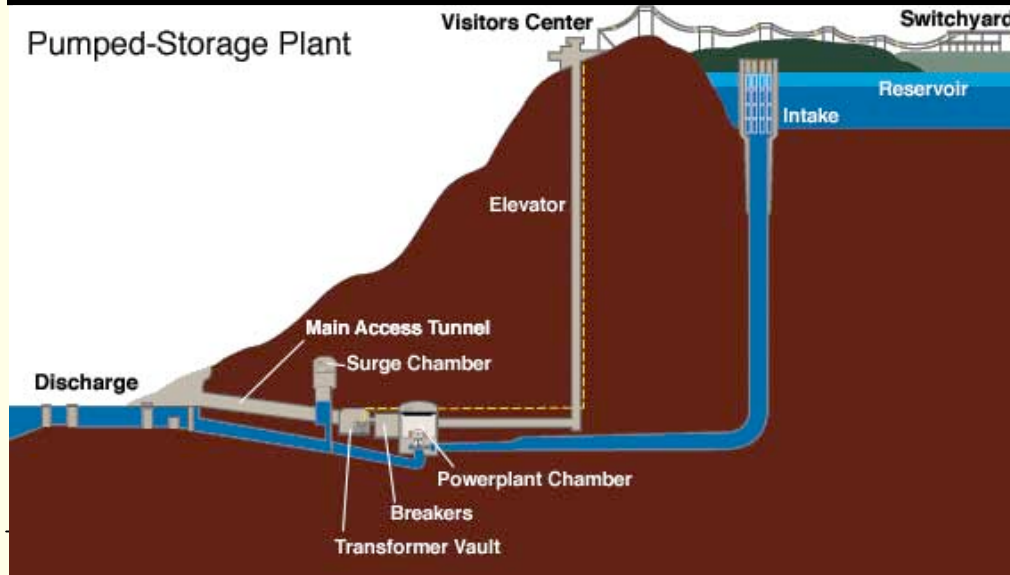
- * **Wide variation of K in shallow depth**
- * **Range of stress ratio : Korea - $30/H + 0.4 \leq K \leq 300/H + 1.0$, (~ 900m)**
World - $100/H + 0.3 \leq K \leq 1500/H + 0.5$, (~ 3000m)

Large underground caverns in Korea

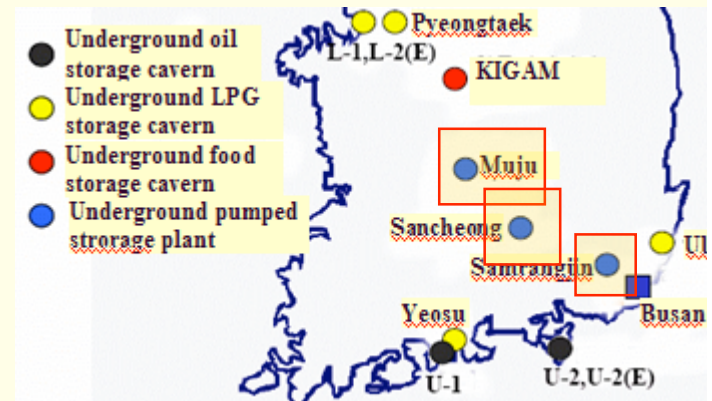


Underground Pumped Storage Plant

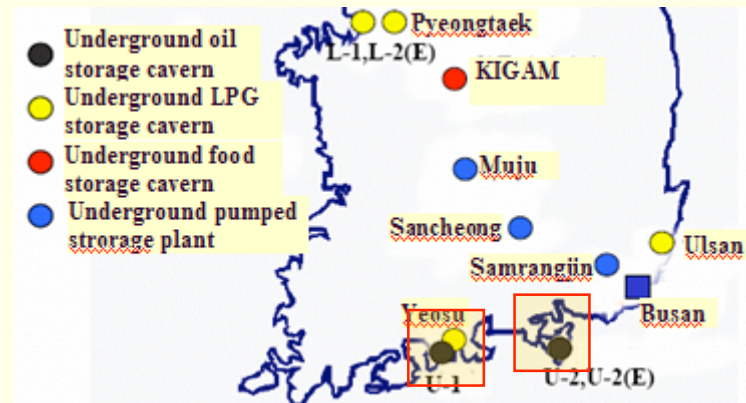
		Cheongpyeong	Samrangjin	Muju	Sancheong
Cavern Info	Rock type	Gneiss	Tuff, Rhyolite	Granitic gneiss	Gneiss
	Depth (m)	350	150	260	250
	shape	Mushroom	Mushroom	Mushroom	egg
	Size (m)	22.5 x 36 x 86	21.5 x 43 x 92	23 x 49.5 x 116	25 x 49.5 x 116



Construction period : ~ 6-7 yrs



Underground Oil Storage Cavern



		U-2	U-1	U-2-1	U-2-2
Cavern Info	Rock type	Granodiorite	Andesite, Tuff	Granodiorite	Granodiorite
	Depth (m)	~ -60	~ -60	~ -60	~ -60
	Size (m)	18 x 30	18 x 30	18 x 30	18 x 30
	Length (m)	875	1,030	678	450

Uni-axial compressive strength: 1,500 ~ 2,000 kgf/cm² Construction period : ~ 4-8 yrs

Concluding Remarks

■ Possible sites

- mountain area
- mines ?

■ Geological conditions

- favorable (expected)
- not much information for deep geological condition
- more detailed geotechnical characterization needed
to reduce potential risks for construction

■ Design and construction

- engineering problems

Thank you for attention!

- *For more information, please contact:*
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- **e-mail: cryu@kigam.re.kr**